HYDRO - ELECTRIC POWER PLANT
AT
BOX CANYON, IDAHO

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A THESIS

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DESIGN OF PROPOSED HYDROELECTRIC POWER PLANT

-at-

BOX CANYON, IDAHO

The projected development is on the Snake River, Lincoln County, Idaho. The site is known as Box Canyon Creek, and is twenty-five miles downstream from the city of Twin Falls, ten miles north of Buhl, and nine miles south of Wendell, in Lincoln County. The inserted map will serve to show the location of the site.

The country immediately about the power site is included in the Twin Falls North Side Segregation under the Carey Act. This is a tract of 150,000 acres already supplied with water and is being rapidly settled and cultivated. Immediately across Snake River, on the opposite side from the location of the power house is the Twin Falls South Side Carey Act project, embracing about 180,000 acres partly supplied with water for irrigation purposes.

It is proposed to use the power output of the plant for supplying energy to small sub-stations where pumps will be operated.


NEVADA

In California, Oregon, Washington, Colorado and a few other western states electrically operated pumping plants have been in use for irrigating the land for a considerable length of time. In some of these states water is pumped from wells where an underground supply is found to exist. In other states the plants are located along small streams, rivers and lakes and are used for lifting water to the adjoining land.

Until four years ago practically nothing was known of irrigation pumping in Idaho. The only plants then in operation consisted of small low-lift stations owned by individuals. The success of these stations, coupled with the installation of larger pumping projects, has done much to bring about wonderful results, which may be gaged by the fact that today a greater acreage of land is watered by electrically operated pumping plants in the state of Idaho than in any other state of the Union, or possibly in any other part of the world. Approximately 125,000 acres of land are under pumping systems already installed, and at least 150,000 acres additional will be watered in a similiar manner in a short period of time.

The general development of the state of Idaho has been more rapid than that of any other state. One instance of this growth is the town of Twin Falls.

Where seven years ago there was merely an uninhabited sagebrush desert today is found a city of 7,500 people, modern in every particular, and surrounded by half a million acres of well-cultivated land. This rapid growth has been due mainly to the development of irrigation enterprises within the state.

The earlier pumping installations were of the gravity type, water being diverted from the streams and distributed over wide territories. The easiest and cheapest developments were the first to be carried to completion. As the country advanced and the demand for irrigated land increased, the more expensive projects were undertaken, and the ones that have lately been put under way are found to require one or more expensive reservoirs, diverting dams, long earth or rock cuts, tunnels and often many miles of side-hill canals or flumes in order to deliver water upon the land. The cost of installing, maintaining and operating these various necessary adjuncts to the modern gravity project is often very considerable.

When it became generally known that the modern electrically operated pumping plant was proving successful on small tracts of land the local engineers estimated that the larger propositions might be equally or even more feasible than the smaller ones. It was soon

shown that the pumping plant was far cheaper in construction and often more reliable and satisfactory than the average gravity system. The greater number of pumping projects in Idaho are located along the course of the Snake River and the plants are built on the banks of this stream. On account of the natural conditions the pump houses are inexpensive to construct, very short pipe lines are necessary, and the water is delivered directly to the land, making it unnecessary to construct any expensive diversion works or long lines of main canals.

Some of the finest and most fertile land in Southern Idaho is so situated that it can be more feasibly watered under a pumping system than by the more familiar gravity methods, and a decided impetus has been given to the pumping business during the past few years.

It has been found that it is much cheaper and better to water a large tract of land with one large pumping plant than with a number of small plants. The machinery efficiency is greater, the losses through seepage and evaporation are reduced, and the cost of installing is lowered by the use of a large pumping plant.

A large part of the land under irrigation

projects in Idaho is segregated under the Carey law, by the provisions of which private companies dispose of land and water rights to settlers at regular drawings under contract with the state. The state contract specifies the manner of development, the amount of water right and the price per acre for which the land and water is to be sold. Many local conditions affect the water supply that it is necessary to provide under any irrigation proposition. The altitude of the land being watered under Idaho irrigation projects varies from 2,200 ft. to as high as 5,500 ft., with the result that where water is required for irrigation for only four months in the higher altitudes it may be required for six months in the lower districts, where the irrigating seasons are longer. On account of the abundant stream flow available for most of the irrigated land in Idaho the farmers have become more or less wasteful of the water, many of them using several times the quantity that would best mature their crops.

Many different kinds of soils are found in Idaho and they absorb water in varying amounts. The land in the lower altitudes is found to require more water than that higher up, owing to the warmer atmosphere and the consequent rapid evaporation. The kind of crop that is raised on a certain piece of land has

a large bearing on the quantity of water that must be made available. Hay crops require more water than grain, grain crops more than potatoes, and potatoes more than fruit trees. Some experienced fruit growers have matured orchards on the lower lands where the maximum supply of water never exceeds 6 in. in six months. On the other hand, some experienced irrigators contend that they must have at least 7 ft. of water in six months in order to grow their crops properly.

The foregoing pages give an idea of the conditions in the vicinity of Box Canyon as regards power usage and characteristics of the surrounding country. We will now proceed with the description and design of the proposed water power development under consideration.

Source of Hydraulic Energy

The source of water supply is a large spring, presumably issuing from an underground river carrying a discharge from the Sawtooth Mountains some fifty miles away. The spring has an unvarying flow of 365 cu. ft. per sec., with a fall of 186 ft. between the spring and Snake River, a distance of one and one-eighth of a mile. The water is clear, soft and warm, issuing from the earth at a temperature of about 58 degrees Fahrenheit, and does not freeze in the coldest

winter. The canyon has no drainage area whatever and no flood waters can be encountered. The stream has been measured a number of times during most every month in the year and no appreciable variation of flow can be noticed. While there is a difference between the figures given by several engineers as to the quantity of water issuing from the spring, this difference apparently arises from the difficulties of measuring such a swift flowing current over many boulders and uneven bottom. These measurements range from 449 cu. ft. per sec. down to 365 cu. ft. per sec., the latter figure being the lowest figure ever given by an engineer.

In making calculations for the available power and size of turbines to be used, it was assumed that the quantity of water discharged was 365 cu. ft. per sec.

Available Head

Levels run from Snake River to the spring show a difference of elevation of 186 ft. In the design of the development, however, it was deemed best to build a dam at a convenient point in the course of the stream to a height of 50 ft., which would a head of 200 ft. from the crest of the dam to the water in Snake River. The site of the dam was chosen at a point about 1,100 ft. downstream from the spring.

Calculations for Available Power

The theoretical horsepower that can be developed by a quantity of water (Q) falling a distance (h) is given by

$$\text{Horsepower} = \frac{Qh}{550}$$

where Q is the quantity of water in lbs. per sec., h the head in feet, and 550 the number of ft.-lbs. per sec. for one horsepower.

With the data at hand the theoretical horsepower will then be

$$\text{Horsepower} = \frac{(365 \times 62.5) \times 200}{550} = 8295.$$

Calculations were made for entrance and friction losses which gave a total loss of 9 ft., or approximately 5 per cent of the available head. This would make the efficiency of the intake and penstock 191/200, or 95.5 per cent.

Reliable authorities give the efficiency of Francis type water turbines as 75 per cent, and the efficiency of large generators as 95 per cent. Using these figures the efficiency of penstock, turbines and generators will be 95.5 x .75 x .95, or 68.1 per cent. The available output of the generators will be 8295 x .681, equals 5575 horsepower, or 4160 kilowatts.

Concrete Dam

The dam is of the arch type, being arched on plan, and is in the statical condition of an arch under pressure. The base is immovably fixed to the foundations by the frictional resistance due to the weight of the structure. For this reason the lowest portion of the dam does not possess full freedom of motion or elasticity and consequently must act as a gravity dam subject to oblique pressure. The weight of the arch itself is conveyed to the base, producing stresses on the horizontal plane, while the water pressure is normal to the extrados, radial in direction, and is transmitted through the arch rings to the abutments. The pressure is therefore distributed along the whole line of contact of the dam with the sides as well as with the ground.

The theoretical profile suitable for an arch dam is a triangle having its apex at the extreme water level, its base width being dependent upon the prescribed limiting pressure. A very high value of maximum stress in comparison with gravity dams can be adopted with safety in the arch-type dam. The profitable use of arch dams is dependent upon the above feature. The adopted values of the limiting stress (s) per unit area have been in the neighborhood of 16 to

20 tons per sq. ft. The average unit stress developed by water pressure is expressed by the formula

$$s = \frac{RHw}{b} \quad \text{or} \quad b = \frac{RHw}{s}$$

in which b equals width in ft. at bottom of dam;

s equals average unit stress;

R equals radius in ft. of extrados;

H equals total height of dam in ft.;

w equals unit weight of water, or 1/36 ton per cu. ft.

In this design s is taken as 18 tons per sq.ft.; R is 212 ft.; H is 60 ft.; then

$$b = \frac{212 \times 60}{18 \times 36} = 19.6 \text{ ft., or } 20 \text{ ft. approx.}$$

The proposed dam is to be constructed of reinforced concrete and extend across the canyon, a distance of 270 feet. The maximum height (60 ft.) extends for a distance of approximately 100 ft., the dam sloping up the sides of the canyon. The profile is vertical on the extrados side, and has an incline of 3.15 inches to the foot on the intrados side. The top of the dam is to be 4 ft. wide. Two mud gates, 8 ft. by 10 ft., closed by 12 in. by 12 in. timbers, are placed at the base of the dam.

The intake forms a part of the dam structure. Its dimensions are 48 ft. long by 13 ft. wide, and it has two hand-operated service gates, one head gate, and the opening to the penstock. The penstock intake is provided with a trash-rack to prevent any foreign material from entering the penstock, and is also provided with a hand-operated relief gate.

A close approximation of the cubical contents of the dam and intake is 4,500 cu. yds. of concrete.

Penstock

The proposed penstock will be 4,840 ft. long, and is to be made of wood stave pipe to a point where the head is 125 ft., which amounts to a hydrostatic pressure of 54.1 lbs. per sq. in. From this point to the power house it will be constructed of riveted sheet steel pipe.

The center of the penstock opening at the intake is 10 ft. below the crest of the dam, while the center of the penstock at the power house is 10 ft. above the level of Snake River. The difference in elevation between Snake River and the crest of the dam is 200 ft., so that the drop of the penstock in 4,840 ft. is 180 ft., or a grade of 3.72 per cent.

From calculations it was found that 3,400 ft. of wood stave pipe will be needed. This wood stave pipe is 8 ft. in diameter and is made of 3-in. staves of Douglas fir. The staves are so milled that when they are assembled they form a pipe of the diameter desired. Staves of various lengths are laid side by side so that the joints are staggered. Each stave is butted against the one immediately preceding it, while saw kerfs, or slits, at the ends receive a metal tongue, thus making the staves continuous and without any joint in the pipe. The laying of the pipe is thus

continued to the end of the line, irrespective of the length. It is this feature, the absence of pipe joints, giving a continuously uniform internal diameter, with absolutely smooth walls, thus minimizing the friction losses, that makes this form of wood stave pipe so desirable for the transmission of water.

The staves are held firmly in place by steel hoops solidly cinched or drawn home until every stave is tightly seated. These hoops are of No. 4, B. & S. gauge, steel wire, .225 in. in diameter, and are spaced 18 in. apart at the intake end of the penstock. As the head increases the spacing between the hoops decreases, so that the spacing at the lower end of the wood pipe is 6 in.

The 1,440 ft. of steel pipe is fastened to the end of the 8-ft. wood stave pipe by a coupling, and then tapers to a diameter of 6 ft. at the surge tank. The steel penstock varies in diameter and thickness with the normal hydrostatic head and hydraulic impact as shown in the following table:

	Length	Diameter	Thickness
First section....	440 ft.	96 in.	.25 in.
Second section...	580 ft.	87 in.	.38 in.
Third section....	420 ft.	72 in.	.57 in.

The velocity of the water through the penstock at normal turbine rating ranges from 8.5 to 10.5 ft.

per sec., the higher value being the velocity at the power house, while the lower value is the velocity at the intake.

The strength of the lower sections of the penstock and the anchoring of the tubes has been designed to give a factor of safety of five when withstanding the full inertia impact of rise in pressure due to the closing of the lower valves. The inertia is greatly eliminated by the use of a surge tank which forms a continuation of the penstock. This tank is constructed of riveted sheet steel, .57 in. thick, and is 180 ft. high and 6 ft. in diameter. It is anchored on a separate concrete foundation, 10 ft. by 10 ft.

The upper portion of the wood stave pipe is protected against inward collapse, due to the emptying of the tubes, by suitable vents.

Power House and Turbine Units

Entering the power house the supply lines are taken through hydraulic valves, 40 in. in diameter, and thence enter the horizontal, inward-flow, reaction type, single discharge waterwheel units. There are three S. Morgan Smith machines equipped with special oil-pressure governors which regulate within 1.5 per cent for load changes from full load to no load. Linked to the governors are synchronous relief valves which, with the closing of the turbine wickets, automatically open a by-pass discharge having a capacity 15 per cent greater than the turbine itself at full load. In this way, despite sudden changes in the turbine gate opening, the amount of water flowing in the penstock is not immediately arrested, but is diverted to the by-pass channel, thus avoiding impact heads due to suddenly stopping the long moving column of water. These synchronous relief valves are also equipped with water saving devices which slowly close the by-pass openings, reducing the penstock flow gradually, without rise in pressure. The relief valve and water saving mechanisms are operated positively by the governors and can be adjusted to work at any desirable time interval for opening and closing the by-pass. The governors are designed to use oil at 200 lbs. pressure and exert a controlling

force of 18,000 ft.-lb. This governor can also be operated by hand.

These units are of 2,000 horsepower capacity and are direct connected to 1250-kilowatt, 2300-volt, 60-cycle, three-phase General Electric alternators. To assist in speed regulation each of the three units carries a 9000-lb. flywheel which adds 58,000 ft.-sq.-lb. of flywheel effect. Each unit has a 25-kilowatt, 125-volt exciter direct connected to the end of the alternator shaft.

Electrical Equipment

The 2300-volt output of the generators is stepped up to a transmission voltage of 33,000 volts by three separate General Electric three-phase, oil-cooled transformers whose oil contents are cooled by water circulated from an independent supply taken from the creek through a 6-in. cast iron pipe.

The 2300-volt bus is equipped with three hand-operated K3 oil switches, and the 33,000-volt bus is equipped with three H2 remote-control oil switches. The 2300-volt bus may be used as a transfer bus, by means of which the machines may be operated as a unit system. The leads from the generators are provided with instrument transformers for switchboard equipment. The busses are made of three copper bars $\frac{1}{2}$ in. thick by 3 in. wide, bolted together and leaving an air space of $\frac{1}{2}$ in. between each bar. They are insulated from the walls by General Electric wall insulators. From the 33,000-volt bus the three lines go through disconnects, choke coils and separate wall outlets. The lines are protected by General Electric aluminum-cell arresters, with horn gaps located above the cells.

The switchboard is of the standard panel type, made by the General Electric Company. It consists of three generator panels and one exciter panel.

Power House Building

The building is to be 60 ft. long by 60 ft. wide, inside dimensions, and constructed of concrete, brick and steel. The distance between the roof girders and the floor will be 25 ft.

The foundation and tail race is made entirely of concrete. The building will consist of a skeleton steel framework, which carries the gable roof trusses and the concrete tile roof. The height to the apex of this gable will be 39 ft. 6 in. The inside walls are of white terra cotta brick, while the outside walls are of common red brick. All window and door frames are of the pressed steel construction and will be of the standard size used in power house buildings.

The generator and turbine room is partitioned off so as to form a room 60 ft. long by 40 ft. wide, spanned by a 15-ton hand-operated crane $21\frac{1}{2}$ ft. above the floor level. The remaining space, which will be 60 ft. long by 18 ft. wide, will contain the transformers, busses, oil switches, arresters, a repair shop and an office.

The transformers and low tension switches and busses will be on the ground floor at the west end of the building. The repair shop and office will also be on the ground floor, at the east end of the building.

Immediately above the transformer floor will be the high tension balcony. The high tension switches and busses will be located on this balcony. The lightning arresters will be placed upon a separate wall balcony just above the high tension balcony. All floors, balconies and stairways will be of reinforced concrete, with polished surfaces.

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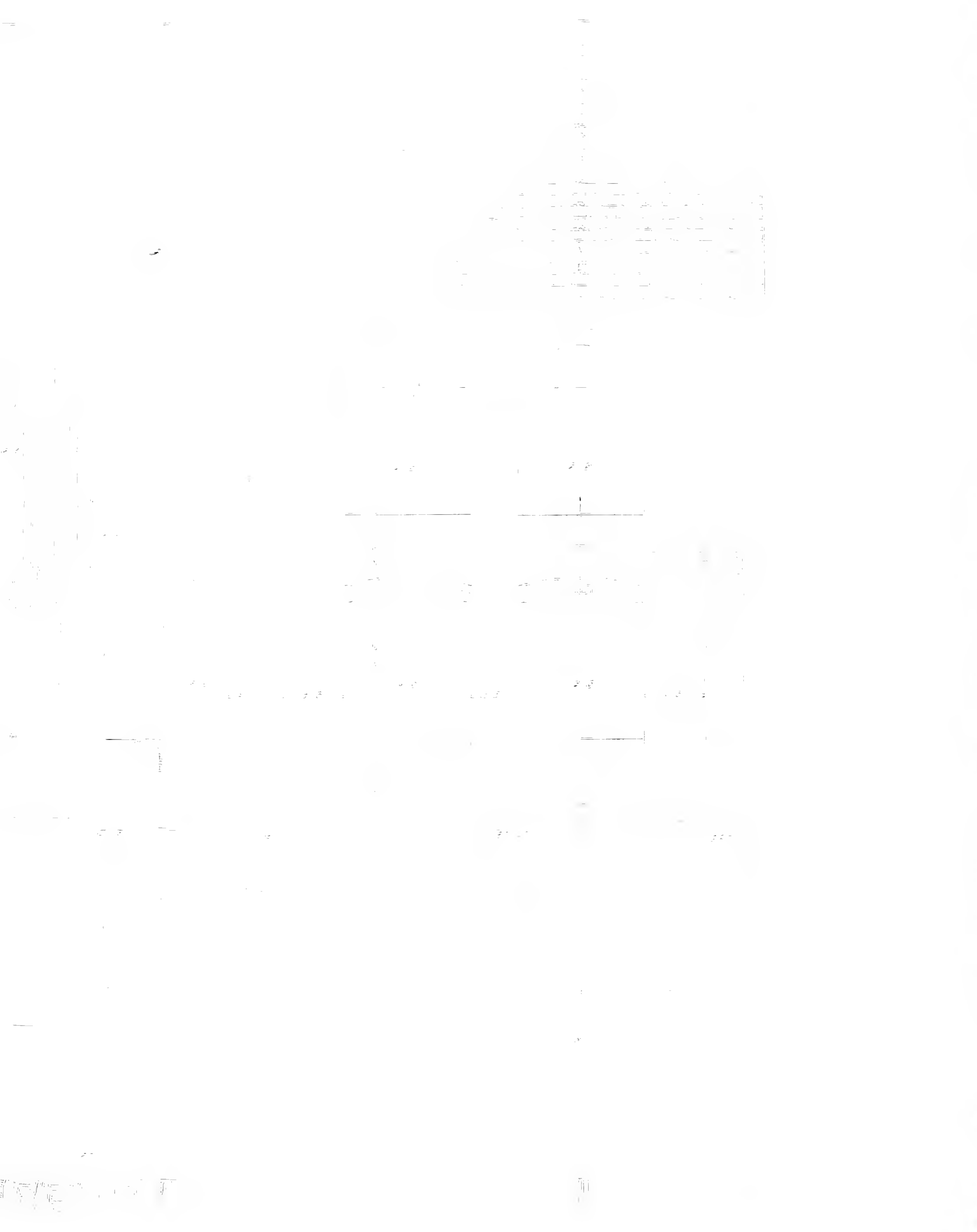
Longitudinal Elevation
of Power House

ELEVATION OF POWER HOUSE

OF

POWER PLANT



Concrete Dam

Plan of

Site

End View of
Power House

End Elevation of
Power House